

## SOIL AND WATER DATA AS ESTIMATES OF GREENHOUSE GAS EMISSIONS FROM AGRICULTURAL FIELD IN KALIMANTAN

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### Abstract

*Land of Kalimantan Island can be classified according to the water regimes into wetland and upland. Wetlands are mainly dominated by Histosol (peat) and Inceptisol (alluvial) soil and used for rice cultivation. Meanwhile, upland are mainly dominated by Ultisol (Podsolik), Alfisol or Oxisol (Latosol) and used for corn, rubber or oil palm plantation. There is few information about the contribution of those agricultural lands to the national or global greenhouse gas (GHG) emissions, partly due to limited measurements of GHG emissions from this island. Results showed that soil pH and soil nitrogen are good estimates of greenhouse gas emission from soils to atmosphere. Temporal emissions of  $N_2O$ ,  $CH_4$ ,  $CO_2$  and their GWP were best be estimated by using pH of soil taken from 0-10 cm depth with equations:  $y = 6.54x + 3.72$ ;  $y = 0.26x + 1.767$ ;  $y = 0.125x + 2.973$ ;  $y = 0.124x + 2.973$  for  $N_2O$ ,  $CH_4$ ,  $CO_2$ , respectively. Seasonal emissions of  $N_2O$ ,  $CH_4$ ,  $CO_2$  and their GWP can be estimated by using nitrogen content of soil with equations for wetlands differ from those for upland soils. The effect of agricultural practices on the GHG estimates will also be discussed.*

### Introduction

Land of Kalimantan Island can be classified according to the water regimes into wetland and upland. Wetlands are mainly dominated by Histosol (peat) and Inceptisol (alluvial) soil and used for rice cultivation. Meanwhile, upland are mainly dominated by Ultisol (Podsolik), Alfisol or Oxisol (Latosol) and used for corn, rubber or oil palm plantation (Anonym, 2007).

There is few information about the contribution of those agricultural lands to the national or global greenhouse gas (GHG) emissions, partly due to limited measurements of GHG emissions from this island. Moreover, the relationship between soil and soil water properties and emissions of greenhouse gasses are poorly understood. These lead to difficulties in assessing the effect of any changes in given soil properties on greenhouse gas emissions. The objectives of this paper is to develop GHGs emission model by using soil and soil water data. The models will also be useful to estimate the possible changes in GHGs emissions if soil or soil water parameters change. This is important to avoid any agricultural practices which can enhance GHGs emissions from soil to atmosphere.

### Materials and Methods

#### Spatial Relationship

To elucidate the relationship between soil or soil water properties and spatial greenhouse gas emissions, soil samples were taken at 10 sites covering an area of about 500,000 ha in South Kalimantan. The area comprised of wetland and uplands, namely secondary forests, paddy fields, upland field grown with cassava, paddy-soybean rotation field and abandoned upland crops field and abandoned paddy field. Nitrous oxide ( $N_2O$ ),  $CH_4$  and  $CO_2$  were measured and published by Hadi *et al* (2005).

Redox potential (Eh) in the field was measured by inserting a platinum electrode in 3 soil depths (i.e. 10, 20 and 30 cm) in as described by Hesse (1975). Ground water-table was measured by inserting a pizometer into the soil. Soil samples were taken from 3 soil depths (0-10, 10-20 and 20-30 cm) at the same time with gas sampling in one meter radius from the chambers. The soils were analyzed for pH, C and N contents, cation exchangeable capacity (CEC), and  $Fe^{3+}$ ,  $NH_4^+$  and  $NO_3^-$  ion concentrations. Soil pH, C and N contents and CEC were determined using methods as described by Page *et al* (1982). Soil ammonium- and nitrate-N were measured in KCl extracts by using nitroprusside

(Anderson and Ingram, 1989) and hydrazine reduction (Hayashi *et al.*, 1997) methods, respectively.

### Seasonal Relationship

To elucidate the relationship between soil or soil water properties and seasonal greenhouse gas emissions, five chamber basements were permanently inserted in wetlands and 12 in upland crop fields. The soil taken from wetland was an Histosol in Amuntai and Gambut sub-districts, while in upland field was an Ultisol in Cempaka sub-district. The wetland comprised of secondary forest and paddy fields. To vary the soil conditions in upland, urea (200 kg ha<sup>-1</sup>), urea (170 kg ha<sup>-1</sup>) + DCD (20 kg ha<sup>-1</sup>) or controlled-release fertilizer LP-30 (214 kg ha<sup>-1</sup>) were incorporated into three plots each and cultivated to corn. Plots without N fertilizer were established.

Gas samples were taken from wetlands in monthly basis for one year using a closed chamber and analyzed for N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> as described by Hadi *et al.* (2005) for Amuntai sub-district and Inubushi *et al.* (2003) for Gambut sub-district. The gas samples from upland were taken at 4, 8, 12, 21, 31, 41, 51, 72 and 92 days after corn planting and analyzed for N<sub>2</sub>O as described by Hadi *et al.* (2008).

Soil samples were taken from upland up to a depth of 30 cm at the day of corn planting and analyzed for soil pH, C and N contents and NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> concentrations, and number of *Nitrosomonas* and *Nitrobacter*. Soil samples were also taken at 41 days after corn planting (when N transformations were expected to be high) and analyzed for NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> concentrations.

Soil-pore water was collected in upland field by inserting a water sampler (DAIKI-8390; Daiki Physicochemical Company, Tokyo, Japan) to a soil depth of 25 cm at the center of four hills of corn plants and sucking water into a 50 mL syringe. The water was then analyzed for inorganic NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> concentrations.

### Model Development

To assess the relationships between soil or soil water properties and gas emissions, correlation and regression analyses were carried out by using SPSS 11.0 software for Windows (SPSS, Chicago, USA). Global

warming potentials (GWP) were firstly calculated prior to statistical analyses. The GWP was calculated by multiplying emissions of N<sub>2</sub>O, CH<sub>4</sub> and N<sub>2</sub>O with their respective warming potentials (2968, 23 and 1 for N<sub>2</sub>O, CH<sub>4</sub> and N<sub>2</sub>O, respectively). Probability values were used in deciding the best estimate model of greenhouse gas emissions from soil and soil water parameters. The smaller the probability values reflect the better model(s).

## Results and Discussion

### Spatial Relationships

There was significant positive correlation between N<sub>2</sub>O emissions and pH of soil taken from 0-10 cm depth and extracted by water or KCl. pH of soil taken from 0-10 cm soil depth was also good estimates of both CH<sub>4</sub> and CO<sub>2</sub>, as well as the GWP of three gases. No statistical significances were found when assessing the relationship between gas emissions and soil parameters, except pH of soil taken from 0-10 cm depth.

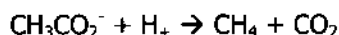
The CH<sub>4</sub> emissions can be predicted from total N, NO<sub>3</sub><sup>-</sup> concentration, soluble C, and Eh of soils from 10-20 cm depth. Water soluble C of soil taken from 10-20 cm depth was also the best estimate of GWP of three gases.

Similarly, the pH, total N, soluble C and Eh of soil taken from 20-30 cm depth can estimate the CH<sub>4</sub> emissions from soil to atmosphere. Carbon dioxide emissions and GWP of three gases can be estimated by soluble carbon of soil taken from 20-30 cm soil depth.

The relationship between soil parameters and gas emissions can be drawn with regression equations shown in Figs. 1-3. Emissions of N<sub>2</sub>O, CH<sub>4</sub>, CO<sub>2</sub> and their GWP can be estimated by using pH of soil taken from 0-10 cm depth with equations:  $y = 6.54x + 3.72$ ;  $y = 0.26x + 1.767$ ;  $y = 0.125x + 2.973$ ;  $y = 0.124x + 2.973$  for N<sub>2</sub>O, CH<sub>4</sub>, CO<sub>2</sub>, respectively (Fig. 1).

It seems that soil pH can be used to estimate the N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> emissions as well as their global warming potentials. Soil pH is a basic soil properties and is almost always obtained during soil survey hence relatively available in most soil-data base. Soil pH is a reflection of H ion concentration in soil. Concentration of H ion directly affect the CH<sub>4</sub>

and CO<sub>2</sub> formations in soil through the following reaction (Jones, 1991):



Positive correlation between soil pH and gas emissions revealed that any effort to increase soil pH, such as liming, will result in an increase of greenhouse gas emissions. Ohtake *et al* (2005) reported an increased in CH<sub>4</sub> formation in laboratory incubation experiment as a result of lime incorporation in wetland soil.

Characteristics of sub-surface soils (10-20 cm and 20-30 cm depth) seem to affect the CH<sub>4</sub> emissions more as compare with surface soil. It is probably due to abundance methanogenic microbes and substrates in this layer (Inubushi *et al.*, 1998; Hadi *et al.*, 2005).

### Seasonal Relationship

Significant relationships between soil and soil-water parameters and gas emissions from wetland are listed in Table 1.

Apart from pH that has been discussed earlier, nitrogen content of soils seem to also be a good estimate of CH<sub>4</sub> and CO<sub>2</sub> emission from wetlands of Kalimantan. Nitrous oxide emissions seemed to also have relationship with total N in soil of wetlands, though the coefficient correlation was not statistically significant at probability < 0.05.

Table 1. Relationships between selected soil parameters and gas emissions from wetlands of Kalimantan

Soil depth	Y	X	Equation	r values
0-10 cm	CH <sub>4</sub>	pH (H <sub>2</sub> O extract)	y = 12.556x - 43.678	0.856
	CO <sub>2</sub>	Total N	y = 214.49x - 1557.4	0.856
	GWP	Total N	y = 258.09x - 2025.7	0.861
10-20 cm	CH <sub>4</sub>	pH (H <sub>2</sub> O extract)	y = 3.5192x + 11.964	0.961
		NO <sub>3</sub> <sup>-</sup>	y = 3.5192x + 11.964	0.946
20-30 cm	CH <sub>4</sub>	pH (H <sub>2</sub> O extract)	y = 16.645x - 54.714	0.924
		NO <sub>3</sub> <sup>-</sup>	y = 0.2737x - 1.8987	0.917
		EC	y = -1.0915x + 19.315	-0.959

The important of N data is specially important for estimation of N<sub>2</sub>O emissions from upland since N<sub>2</sub>O has significant correlation with soil NH<sub>4</sub><sup>+</sup> concentration and [NH<sub>4</sub><sup>+</sup> + NO<sub>3</sub><sup>-</sup>]. The N<sub>2</sub>O emissions can be estimated using soil NH<sub>4</sub><sup>+</sup> concentration and [NH<sub>4</sub><sup>+</sup> + NO<sub>3</sub><sup>-</sup>] by using equation: y = 9,0002x - 22,663; y = 27,089x - 414,19; y = 8,1068x - 28,87 for NH<sub>4</sub><sup>+</sup> concentration at the day of corn planting, NH<sub>4</sub><sup>+</sup> concentration at 40 days after corn planting and [NH<sub>4</sub><sup>+</sup> + NO<sub>3</sub><sup>-</sup>] at the day of corn planting, respectively. Nitrous oxide emissions (Y) can also be estimated by number of NH<sub>4</sub><sup>+</sup> oxidizer (x) with equation: y = 2,738x - 156,14.

These results suggest that greenhouse gas may also be estimated using N data which is usually available during a soil mapping survey and successive data-base package. Positive correlations between soil nitrogen and greenhouse gas emissions revealed that any effort to increase soil nitrogen content such as N fertilization may increase the greenhouse gas emissions from agricultural fields to the atmosphere. This might have a trade-off effect to the promotion of crop production. Effort should be done to keep the gas emissions low while applying plant-growth promoter such as fertilizer. The use of nitrification inhibitor may be useful to overcome this trade-off effect (Hadi *et al.* 2008).

### Conclusions and Recommendations

It can be concluded that soil pH and soil nitrogen are good estimates of greenhouse gas emission from soils to atmosphere. Temporal emissions of N<sub>2</sub>O, CH<sub>4</sub>, CO<sub>2</sub> and their GWP were best be estimated by using pH of soil taken from 0-10 cm depth with equations: y = 6.54x + 3.72; y = 0.26x + 1.767; y = 0.125x + 2.973; y = 0.124x + 2.973 for N<sub>2</sub>O, CH<sub>4</sub>, CO<sub>2</sub>, respectively. Seasonal emissions of N<sub>2</sub>O, CH<sub>4</sub>, CO<sub>2</sub> and their GWP can be estimated by using nitrogen content of soil with equations for wetlands differ from those for upland soils. It is recommended to consider these models in predicting the greenhouse gas emission as effected by agricultural practice(s).

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